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NSWCDD/TR-94/89

USE OF THE NSWCDD WEATHER DATABASES FOR PREDICTION OF ATMOSPHERIC TRANSMISSION IN COMMON THERMAL IMAGING SENSOR BANDS

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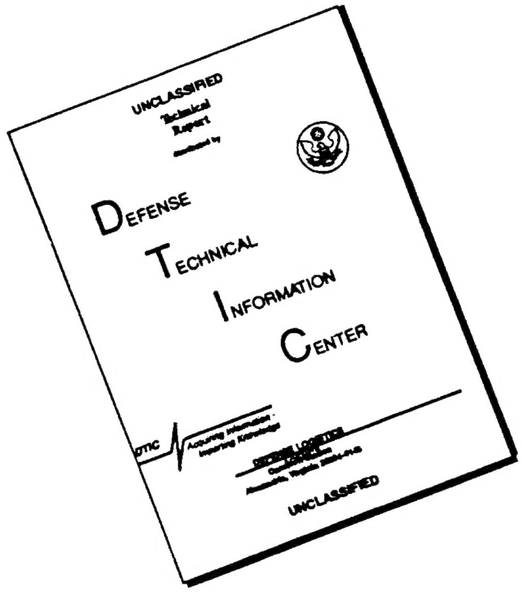

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FOREWORD

Many U.S. Navy programs need to make predictions of thermal imaging sensor (TIS) performance against various threats. An important factor in calculating performance ranges is the atmospheric transmission. Weather information previously combined into databases was processed into a form that would allow simple estimates of TIS band atmospheric transmission at any given range at various levels of probability of occurrence. This report describes these databases and the TIS band atmospheric transmission modeling that was done using them.

This report has been reviewed by Roger Carr, Head, Electro-Optical Systems Branch and Stuart Koch, Acting Head, Search and Track Division.

Approved by:

THOMAS C. PENDERGRAFT, Head
Ship Defense Systems Department

ABSTRACT

An important factor in calculating performance ranges for thermal imaging sensors (TIS) is the atmospheric transmission. The infrared energy from a target must first pass through a section of the atmosphere before reaching the TIS aperture. This atmosphere will attenuate the signal. The amount of attenuation depends on the sensor band and weather conditions, and may have a considerable effect on the strength of the received signal. Usually a complex program such as LOWTRAN 7 is used to calculate the atmospheric transmission for a given range and set of weather conditions, but this can be time-consuming and involves the specification of many variables. In an attempt to simplify this process, weather information previously combined into databases was processed into a form that would allow simple estimates of TIS band atmospheric transmission at any given range at various levels of probability of occurrence. Three of these databases, the *Random 400* (R400), the *Random 384* (R384), and the *Random 10,000* (R10K), represent a *worldwide sample* of a larger collection of weather data, known as the Naval Surface Warfare Center, Dahlgren Division Environmental Database. A fourth database, the *Persian Gulf 720* (PG720), describes only one specific location. This report describes these databases and the TIS band transmission modeling that was performed using them.

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INTRODUCTION

Many U.S. Navy Programs need to make predictions of thermal imaging sensor (TIS) performance against various threats. One important factor in calculating performance ranges is the atmospheric transmission. The infrared (IR) energy from the target must first pass through a section of the atmosphere before reaching the TIS, and this atmosphere will attenuate the signal. The amount of attenuation depends on the sensor band and weather conditions, and may have a considerable effect on the strength of the received signal. Usually a complex program such as *LOWTRAN 7*[1] is used to calculate the atmospheric transmission for a given range and set of weather conditions, but this can be time-consuming and involves the specification of many variables. In an attempt to simplify this process, weather information previously combined into databases was processed into a form that would allow simple estimates of TIS band atmospheric transmission at any given range at various levels of probability of occurrence. Three of these databases, the *Random 400* (R400), the *Random 384* (R384), and the *Random 10,000* (R10K), represent a *worldwide sample* of a larger collection of weather data, known as the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) Environmental Database. A fourth database, the *Persian Gulf 720* (PG720) describes only one specific location. This report describes these databases and the TIS band transmission modeling that was performed using them.

HOW THE DATA IS USED

The atmospheric transmission is typically expressed as a number between zero and one. This number, referred to in this report as τ_{ATM}, is usually determined by a complex calculation that takes into consideration many atmospheric components and the complete spectral response of the TIS of interest. For many purposes, useful information can be obtained by examining the transmission statistics over the mid-wave IR band of 3.4 to 5 µm and the long-wave IR band of 8 to 12 µm, the typical TIS wavebands. The traditional Beer's Law equation, shown as equation (1), is not usually very accurate when applied to average transmission over a wavelength band.

$$\tau_{ATM} = e^{-\alpha R} \tag{1}$$

By adding a second parameter, β, as shown in equation (2), a second degree of fitting is available to express the band-averaged transmission to be expected at a given level of probability of occurrence.

$$\tau_{ATM} = e^{-\alpha R^{\beta}} \tag{2}$$

Equation (2) requires the specification of two atmospheric attenuation coefficients, α and β, to calculate the transmission for a particular set of conditions, as well as the range, R, in kilometers (km). The addition of a second variable to the exponential equation allows for much more accurate curve fitting of the data points, thus more accurate predictions of the transmission can be made by its use. These terms (α and β) are listed in some of the tables in this report and are associated with a particular weather *percentile*. Refer to Appendix A for a description of how the coefficients were generated.

These percentiles represent differing degrees of stringency in defining the environment. For example, the *70% point* means that a calculation using these coefficients will yield an IR transmission (in the given spectral band) worse than or equal to 70 percent of the data points in the given database. Of course, these broad-band, flat-spectral calculations are only estimates of the band-average transmission for any given TIS, but they provide a good starting point for TIS range predictions and band comparison studies. These predictions are optimized for ranges out to 20 km. Although the coefficients are still valid at larger ranges, the predictions will become less accurate and are not recommended for ranges significantly greater than 20 km.

NSWCDD ENVIRONMENTAL DATABASE

NSWCDD (Code F44) has a *weather database* consisting of over 10,000 sets of surface ship weather observations and calculated IR parameters. This database was created in the late 1970's by Dr. Barry S. Katz (NSWCDD, White Oak, Maryland) and Dr. Kenneth C. Hepfer (NSWCDD, Dahlgren, Virginia) to provide a statistical basis for electro-optical (E-O) sensor performance predictions. Surface marine weather observations in the database cover the period of 1964 to 1973 and were provided by the Naval Weather Service Detachment in Ashville, North Carolina. Each weather observation contains cloud cover data and the meteorological parameters required to calculate the atmospheric transmission. This information consists of location, date, time, wind speed and direction, observed visibility, pressure, air and sea temperature, dew point, cloud cover, wave height, and present weather indicator.[2]

Figure 1 depicts the worldwide locations for which data was obtained. Data was gathered by both dedicated weather observation ships or stations (designated with single letter codes) and passing ships (designated with number codes or letter-number codes). While most of the observations were made in the open ocean, there are some coastal data samples that may be used to analyze littoral environments. This original superset of weather observations was reduced by random sampling to produce 14 geographic samples consisting of 60 observations per month for all 12 months. The 60 observations per month were selected to provide the proper mix of day and night based on the latitude and month of the year. In addition to these 14 geographic samples, some smaller samples of observations are available for some other locations.[3] Table 1 shows the 14 locations for which there exist samples of 60 observations per month for 12 months. (These 14 locations are highlighted on the map. Note that some regions in Table 1 contain data from two widely spaced locations; e.g., locations *1* and *2* in the Mediterranean Sea or locations 11 and 12 near Indonesia.)

TABLE 1. LOCATIONS OF 60 OBSERVATIONS FOR 12 MONTHS

Region	Latitude	Longitude	Location Name Code
Mediterranean	32-35 N 36-37 N	33-37 E 0-1 E	1 2
Caribbean	10-12 N 15-17 N	79-81 W 76-78 W	5 6
South China Sea	17-19 N	106-108 E	9
Indonesia	6-9 S 6-10 S	116-120 E 153-156 E	11 12
South African Coast	30-32 S	30-36 E	AF1
Arabian Sea	20-24 N	60-65 E	IN1
Arabian Sea	12-18 N	64-69 E	IN2
Arabian Sea	10-17 N	55-59 E	IN3
Arabian Sea	1-8 N	50-59 E	IN4
Gulf of Oman	20-24 N	58-59 E	IN5
Norwegian Sea	65-67 N	0-4 E	M
North Atlantic	52.3-54.3 N	17.8-20.8 W	J
North Atlantic	44-46 N	15-17 W	K
North Pacific	27.5-30.5 N	133-137 E	T*

* The sample for T does not include the months of June, August, September, and November.

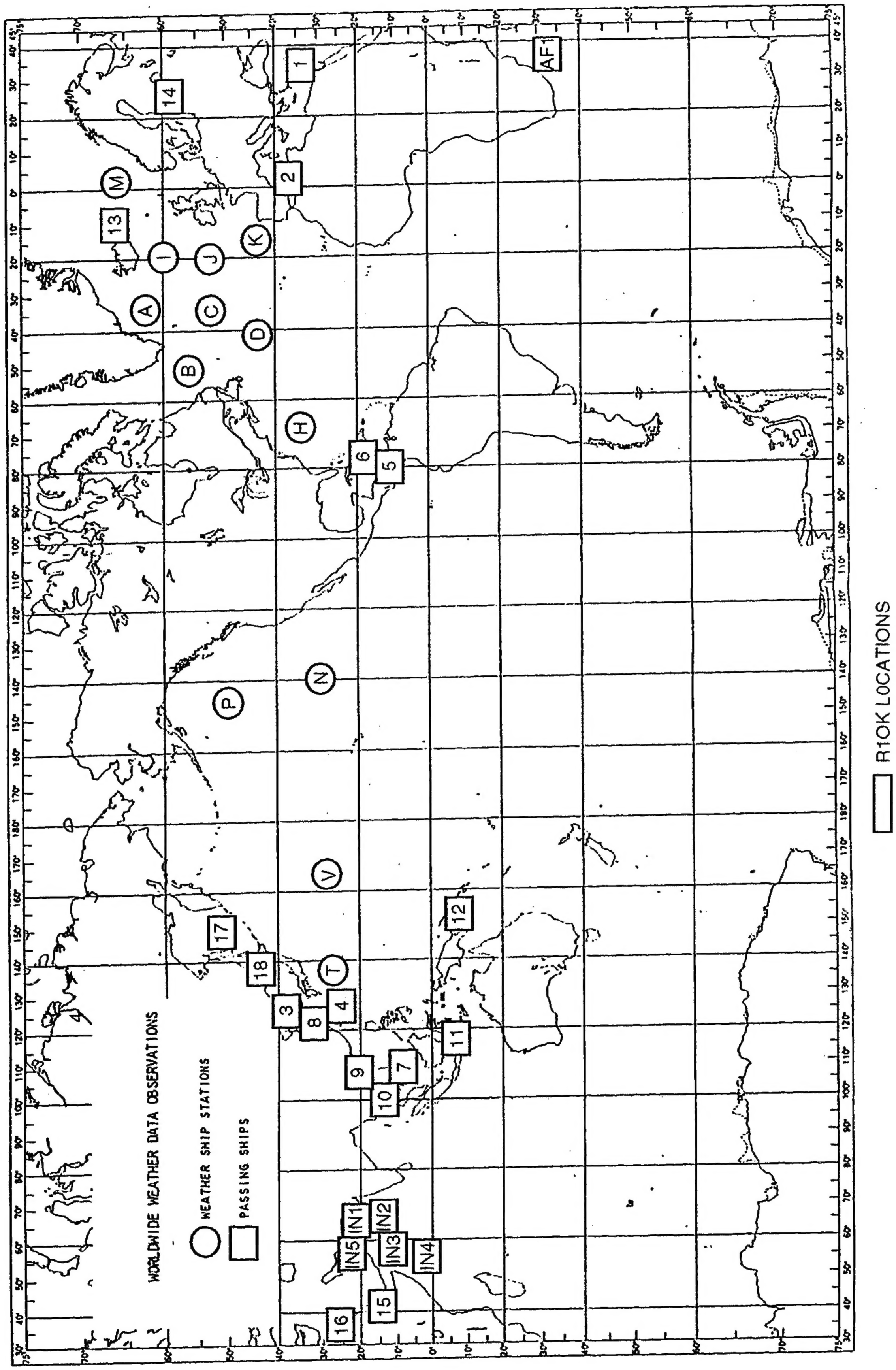

FIGURE 1. WORLDWIDE WEATHER DATA LOCATIONS

This database was compiled for the SEAFIRE and AN/SAR-8 programs and constitutes the source from which the R400, R384, PG720, and R10K samples (to be described later) were drawn. This database and selected subsets are used to represent worldwide or regional marine environments for statistical assessment of IR sensor performance. Refer to Appendix B for further descriptions and formats of the data file contents.

RANDOM 10,000 DATABASE

The R10K sample consists of all the observations described in Table 1. It does not include the various locations for which smaller samples are available. Because location *T* is missing 4 months of data and a few other locations are short one or two observations, the actual size of the sample is about 9800 observations. Because of the size of this sample and the time involved in performing any type of detailed calculations using this data, it is seldom used as a worldwide sample for statistical performance evaluation. In one instance, when it was used in its entirety, the broad conclusions reached were generally similar to those that had been obtained from use of the R400 sample. Table 2 contains coefficients used to predict transmission as generated from the R10K database.

TABLE 2. COEFFICIENTS TO PREDICT TRANSMISSION FOR THE R10K

Percentile	3.4 to 5 µm α_{ATM}	3.4 to 5 µm β_{ATM}	8 to 12 µm α_{ATM}	8 to 12 µm β_{ATM}
10% point	0.19348	0.43123	0.12457	0.14553
25% point	0.21720	0.44424	0.19128	0.14115
50% point	0.24525	0.45535	0.32171	0.14293
70% point	0.26952	0.42985	0.39027	0.14390
80% point	0.29248	0.39738	0.42221	0.14326
85% point	0.31563	0.36413	0.44335	0.14289
90% point	0.36937	0.29212	0.47388	0.14048
95% point	0.56553	0.17024	0.55205	0.13106

RANDOM 400 DATABASE

The R400 sample was originally assembled for the AN/SAR-8 program as a *worldwide weather* data file. The size of this file was selected as a reasonable compromise between computer run time and statistical accuracy on a multilocation worldwide basis. Locations were chosen to represent both areas where aerosol scattering is significant and where molecular absorption dominates. The sample is (approximately) uniform with respect to time of day and time of year, and includes observations from the following geographic locations found in Table 3.[4]

TABLE 3. R400 WEATHER OBSERVATIONS SUMMARY

Region	Number of Observations	Latitude	Longitude	Location Name Code
Norwegian Sea	50	65-67 N	0-4 E	M
North Atlantic Weather Ship J*	100	52.3-54.3 N	17.8-20.8 W	J
Mediterranean Sea	100	32-25 N 36-37 N	33-37 E 0-1 E	1 2
Mid-Arabian Sea	50	12-18 N	64-69 E	IN2
Flores Sea Coral Sea**	100	6-9 S 6-10 S	116-120 E 153-156 E	11 12

* Approximately 450 mi west of Ireland
**Near Indonesia

Figure 2 shows the R400 locations (with corresponding number of data points) graphically on a map of the world.

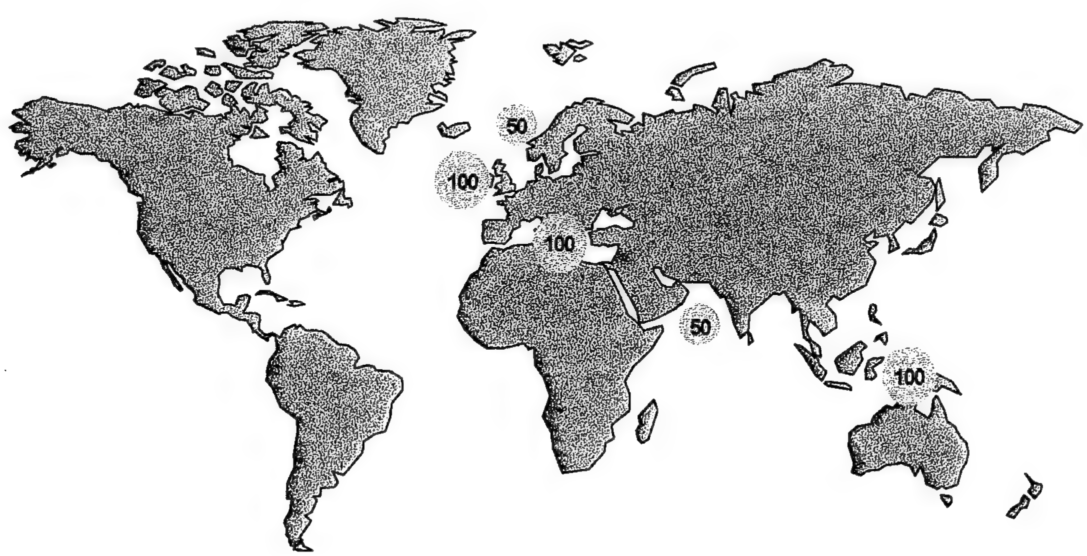

FIGURE 2. LOCATION AND NUMBERS OF R400 SAMPLES

Table 4 contains coefficients used with equation (2) to predict the transmission as generated from the R400 database. These coefficients provide a good estimate of the transmission out to at least 20km.

TABLE 4. COEFFICIENTS TO PREDICT TRANSMISSION FOR THE R400[5]

Percentile	3.4 to 5 μm α_{ATM}	3.4 to 5 μm β_{ATM}	8 to 12 μm α_{ATM}	8 to 12 μm β_{ATM}
10% point	0.46450	0.60692	0.13377	0.85766
25% point	0.51896	0.60212	0.18370	0.87567
50% point	0.64507	0.56790	0.33349	0.88109
70% point	0.72821	0.54521	0.50976	0.88056
80% point	0.75606	0.54707	0.55940	0.88230
85% point	0.77212	0.56045	0.58038	0.88297
90% point	0.80774	0.59999	0.60764	0.88794
95% point	0.94043	0.68741	0.66784	0.88851

RANDOM 384 DATABASE

The R384 is a more recent database developed by Dr. Kenneth Hepfer in June 1993. It includes an equal number of observations (96) to represent the Baltic Sea, the *Yellow Sea*, the Gulf of Oman, and the Caribbean Sea. In establishing this database, it was desired to represent each of these four areas by eight randomly selected weather samples per month for a total of 384 samples. For the Caribbean Sea and the Gulf of Oman, an exact selection of eight samples per month were obtained using data from the R10K database.

For the Baltic Sea and the *Yellow Sea*, samples were made up from available weather data from the nearest areas. For the Baltic Sea, 60* observations were taken from the Gulf of Finland, which is just off the Baltic Sea. These observations were supplemented with 36* observations from Weather Ship J, which is at approximately the same latitude but in the open ocean.

*The original R384 sample had 72 observations from the Gulf of Finland supplemented by 24 from Weather Ship J. It was recently discovered that 12 of the 72 observations from the Gulf of Finland were duplicates and in April of 1995, the 12 duplicates were replaced with another 12 observations from Weather Ship J. In addition, it was discovered that the first line of data from Weather Ship J was corrupted when the original sample was put together and that line of data was repaired when the duplicates were replaced. Examination of the original and revised sample showed no significant change in the transmission statistics for either the mid-wave or long-wave IR bands.

There were 77 observations available from the region between the *Yellow Sea* and the East China Sea. These 77 samples are referred to as *Yellow Sea*. These observations were supplemented with 19 observations from the central portion of the East China Sea. Table 5 shows the distribution of all of the samples.[6]

TABLE 5. DISTRIBUTION OF OBSERVED SAMPLES FOR THE R384

Month	Gulf of Finland	North Atlantic/ Weather Ship J	Yellow Sea	East China Sea	Caribbean Sea	Gulf of Oman
January	0	8	8	0	8	8
February	0	8	1	7	8	8
March	1	7	7	1	8	8
April	2	6	4	4	8	8
May	1	0	3	5	8	8
June	7	0	7	1	8	8
July	19	0	9	0	8	8
August	4	0	7	0	8	8
September	9	0	8	0	8	8
October	11	0	10	0	8	8
November	0	5	4	1	8	8
December	6	2	9	0	8	8

Figure 3 shows the R384 locations (with the corresponding number of data points) on a map of the world.

Table 6 is a summary of the R384 sample, which is made up of randomly selected weather observations.

Table 7 contains coefficients used with equation (2) to predict the transmission as generated from the R384 database. These coefficients provide a good estimate out to at least 20 km. The full data set for the R384 sample is available on the Internet via anonymous FTP. To access this data, select the *R384 Environmental Sample* link on the NSWCDD World Wide Web home page at *http://dias.nswc.navy.mil*. First view the ASCII text file *R384.TXT* for information.

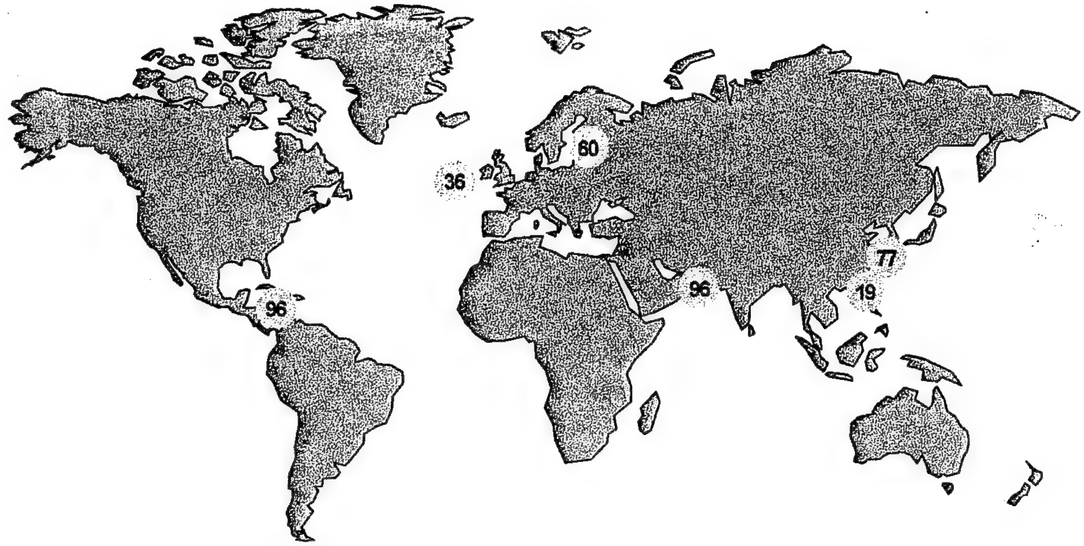

FIGURE 3. LOCATION AND NUMBERS OF R384 SAMPLES

TABLE 6. R384 RANDOM WEATHER OBSERVATIONS SUMMARY[6]

Region	No. of Observations	Latitude	Longitude	Location Name Code
Gulf of Finland	60	59-61 N	22-30 E	14
North Atlantic/ Weather Ship J	36	52-54 N	18-21 W	J
Yellow Sea	77	31-33 N	122-124 E	8
East China Sea	19	24-26 N	124-126 E	4
Gulf of Oman	96	20-24 N	58-59 E	IN5
Caribbean	96	10-17 N	76-81 W	5, 6

TABLE 7. COEFFICIENTS TO PREDICT TRANSMISSION FOR THE R384[5]

Percentile	3.4 to 5 μm α_{ATM}	3.4 to 5 μm β_{ATM}	8 to 12 μm α_{ATM}	8 to 12 μm β_{ATM}
10% point	0.48351	0.58219	0.14316	0.85943
25% point	0.56137	0.57989	0.21926	0.88006
50% point	0.67340	0.57156	0.41487	0.88614
70% point	0.72825	0.56431	0.52054	0.88492
80% point	0.75743	0.57004	0.57288	0.88366
85% point	0.77748	0.57151	0.59310	0.88554
90% point	0.81578	0.58742	0.63084	0.88640
95% point	0.98757	0.69721	0.72255	0.92409

PERSIAN GULF 720 DATABASE

The PG720 sample is the set 60 observations per month, labeled Gulf of Oman (code IN5) as described in Table 1. The location of this regional sample is actually somewhat south of the Gulf of Oman in the Arabian Sea just off the coast of Oman. The observations in this sample came from the marine areas within the limits of 20-24 north latitude and 58-59 east longitude. Table 8 contains the coefficients used to predict transmission as generated from the PG720 database.

DATA LIMITATIONS

- A more detailed transmission analysis may require a spectral atmospheric transmission to more accurately determine TIS performance. The band-average coefficients presented in this report are intended to provide a quick estimate of performance ranges. More accurate calculations that use the spectral response of the sensor and spectral variations in target signature will benefit from such an expanded spectral version of this model.

TABLE 8. COEFFICIENTS TO PREDICT TRANSMISSION FOR THE PG720

Percentile	3.4 to 5 µm α_{ATM}	3.4 to 5 µm β_{ATM}	8 to 12 µm α_{ATM}	8 to 12 µm β_{ATM}
10% point	0.61407	0.51678	0.25399	0.86634
25% point	0.65818	0.51707	0.33741	0.87033
50% point	0.71219	0.52933	0.46957	0.87486
70% point	0.75095	0.53539	0.54834	0.88054
80% point	0.77125	0.54087	0.59656	0.88092
85% point	0.78381	0.54936	0.61977	0.88059
90% point	0.80013	0.56472	0.66070	0.88422
95% point	0.83305	0.58998	0.71566	0.89030

- Data used to compile the previously described weather databases was taken close to the surface; therefore, caution should be used when applying this to high-altitude target scenarios. These databases are recommended for use with sea-level scenarios only.

- The previously discussed calculations were made using the LOWTRAN 7 *Navy Maritime* Aerosol model. However, in littoral regions this may not be the most appropriate. The user must still select the most appropriate aerosol model and associate parameters based on the weather data location.

REMARKS

Comments and suggestions are always appreciated and should be addressed to the authors, who can be reached at

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4. Hepfer, Kenneth C., *Random 400 (R400) Weather Datafile*, Code F44, NSWCDD, internal report.

5. NSWCDD F44 Memo, Subj: *R*400 and *R*384 Atmospheric Attenuation Models, Dahlgren, VA, 5 Nov 1993.

6. Hepfer, Kenneth C., *R384 Environmental Sample*, Code F44, NSWCDD, internal report.

APPENDIX A

HOW THE TRANSMISSION COEFFICIENTS WERE GENERATED

The following methodology was applied to each weather database described in this report.

- Weather observation data were formatted to create *LOWTRAN 7* input files.

- For each weather observation, *LOWTRAN 7* was run multiple times to calculate spectral horizontal transmission at ranges of 10 and 20 km. The calculations reported here were made using the Navy Maritime Aerosol model with the default air mass parameter (3), except when Visibility < 1 km, the Visibility value was entered.

- At each range, the band-averaged transmission was calculated over several bands and sub-bands. For the 3.4 to 5 µm and 8 to 12 µm bands (listed in Appendix B, Table B-6), the spectral transmission over the band was weighted by the temperature derivative of the blackbody function (Plank's Law) at 293 K.

- The band-averaged transmission values for the two ranges, R in kilometers, were fit to an equation of the form.

$$\tau_{ATM} = e^{EXT*R\left(\frac{10}{R}\right)^{XN}} \qquad \text{(A-1)}$$

  where R is in kilometers, EXT is the extinction coefficient at 10 km, and XN is a measure of the deviation from Beer's Law.

- For each observation, the values of EXT and XN for each band and sub-band were written to a file along with the weather observation data and other summary optical and radio frequency parameters derived from the weather data. See Appendix B for a description of the contents and format of this file.

- The EXT and XN parameters from the 3.4 to 5 µm and 8 to 12 µm bands were extracted from the appropriate database and arranged in a spreadsheet.

- Transmissions were calculated (using the EXT and XN parameters) for all records in the database for a large number of ranges.

- All transmissions in the database for a given range were sorted from highest to lowest.

- For each percentile analyzed, a sorted data point was selected, corresponding to a given percentile; i.e., point 361 out of 400 would be the 90 percent (or greater) transmission point for the R400. This was done for each of the many ranges selected, and a corresponding transmission was determined and noted.

- Once a complete set of range vs. transmission data was compiled for a given percentile, the data was curve fit to the equation

$$\tau_{ATM} = e^{-\alpha R^{\beta}} \tag{A-2}$$

- This allowed determination of α and β for each weather percentile. These coefficients are documented in Tables 2, 4, 7, and 8 in the body of the report. This equation was used rather than Equation (B-2) in Appendix B since it is simpler and avoids an undefined result at R=0.

- At any range greater than zero, the two equations are equivalent with the substitution

$$\begin{aligned} \beta &= 1 - XN \\ \alpha &= EXT*10^{XN} \\ XN &= 1 - \beta \\ EXT &= \alpha*10^{-XN} \end{aligned}$$

- The choice between the two forms of the equations is mostly personal preference. The α,β form is simpler and avoids the undefined result at Range = 0, while the EXT,XN form has parameters that carry some intuitive information.

  EXT is the extinction coefficient at 10 km.
  XN is a measure of the deviation from Beer's Law.

- These coefficients in Tables 2, 4, 7, and 8 in the body of the report could then be used with Equation (A-2) to predict the transmission corresponding to a given weather percentile.

APPENDIX B

DATA FORMAT

The data format used for the Naval Surface Warfare Center, Dahlgren Division Environmental database and subset samples consists of five ASCII lines per observation and is known as *Format 5*. The five lines per observation were written using the following FORTRAN code shown in Table B-1.

TABLE B-1. *FORMAT 5* USED FOR WEATHER DATABASES

```
61 format(1x,a5,5(1x,i2),1x,i1,1x,i3,1x,i4,1x,i2,2(1x,f5.1),
  11x,f6.1,1x,f4.1,1x,f5.2,2(1x,f4.1))
62 format(6x,2(1x,f5.2),1x,i2,2(1x,f4.1),5(1x,i2),1x,f5.0,1x,
  1e10.3,1x,f5.2)
63 format(6x,5(1x,f7.4,1x,f4.3))
64 format(6x,f6.2,1x,f6.1,3(1x,f7.4))
65 format(2x,7(1x,f5.3,1x,f4.3))

   write(6,61) lname,iyr,imo,ida,ihr,igmt,iquad,ilat,ilong,iweat,
  1            ta,ts,ap,rh,ahgm,waveh,swellh
   write(6,62) wndspd,avwsd,iwindd,visro,viscal,itc,lcc,ilc,imc,
  1            ihc,cht,cn2,rnrt
   write(6,63) ext055,xn055,ext080,xn080,ext106,xn106,
  1            ext34_5,xn34_5,ext8_12,xn8_12
   write(6,64) delta,ns,xmmt17,xmmt35,xmmt95
   write(6,65) ext34_38,xn34_38,ext38_42,xn38_42,ext44_46,
  1            xn44_46,ext46_48,xn46_48,ext48_5,xn48_5,
  2            ext8_10,xn8_10,ext10_12,xn10_12
```

A description of all variables is provided in Tables B-2 through B-6. In cases where several different names are given for a variable, the additional names are for historical continuity.

In the database records, *EXTxxx* is defined as

$$EXTxxx = \frac{-ln(\tau_{ATM}(10)}{10} \tag{B-1}$$

where $\tau_{ATM}(10)$ is band-averaged transmission at 10 km, averaged over the *xxx* band. For the broad 3.4 to 5 μm and 8 to 12 μm bands, the spectral transmission was weighted by the temperature derivative of the blackbody function (Plank's Law) at 293 K. This is typical of the weighting applied to thermal imaging sensors detecting small temperature differences. For the narrower sub-bands, the spectral transmission was weighted by the value of the blackbody function at 500 K minus the value of the blackbody function at 293 K. This higher temperature is typical of the aerodynamic heating of supersonic missiles.

At any range *(R)*, band-averaged transmission is approximated by

$$\tau_{ATM} = e^{-EXTxxx \cdot R \cdot \left(\frac{10}{R}\right)^{XNxxx}} \tag{B-2}$$

where *xxx* denotes the spectral band identifier. Note that this is a slightly different form of Equation (2) found in the main body of the report.

The range dependence parameter, *XNxxx,* is adjusted to give the correct band-averaged transmission at 20 km using the following equation.

$$XNxxx = 1 - \left[\frac{ln\left(\frac{ln(\tau_{ATM}(10)}{ln(\tau_{ATM}(20)}\right)}{ln\left(\frac{10}{20}\right)} \right] \tag{B-3}$$

As documented in the body of this report, a simpler form of Equation (B-2) is used to describe the band-averaged transmission at a given probability of occurrence.

$$\tau_{ATM} = e^{-\alpha R^{\beta}} \tag{B-4}$$

At any range greater than zero, the two equations are equivalent with the substitution

$$\begin{aligned} \beta &= 1 - XN \\ a &= EXT*10^{XN} \\ XN &= 1 - \beta \\ EXT &= a*10^{-XN} \end{aligned}$$

The choice between the two forms of the equations is mostly personal preference. The a,β form is simpler and avoids the undefined result at Range = 0, while the EXT,XN form has parameters that carry some intuitive information.

EXT is the extinction coefficient at 10 km.
XN is a measure of the deviation from Beer's Law.

TABLE B-2. FORMAT LINE #1

Format	Units	Variable Name(s)	Description
1X			Blank
A5		LNAME,IDL,ALOC	Location Name
1X,I2	years	IYR,IYEAR	Year of observation (since 1900)
1X,I2	months	IMO,IMONTH	Month of observation
1X,I2	days	IDA,IDAY	Day of observation (day of month)
1X,I2	hours	IHR,IHOUR	Hour of observation (local time)
1X,I2	hours	IGMT	Hour of observation (universal time commonly called Greenwich Mean Time)
1X,I1	Code	IQUAD	Quadrant ID: 1 = North and West 2 = North and East 3 = South and West 4 = South and East 0 = Use sign of Lat. and Long. For all sets of 60 obs/month, IQUAD=0 and Lat. and Long. have sign added
1X,I3	degrees	ILAT	Latitude: if IQUAD=0, then North is positive and South is negative
1X,I4	degrees	ILONG	Longitude: If IQUAD=0, then West is positive and East is negative
1X,I2	Code	IWEAT	Weather Indicator (0 to 99)
1X,F5.1	celsius	TA,TAIRD	Air Temperature
1X,F5.1	celsius	TS,TSEA	Sea Temperature
1X,F6.1	millibar	AP, AIRPRO	Air Pressure
1X,F4.1	percent	RH	Relative Humidity
1X,F5.2	gm/m3	AHGM	Absolute Humidity
1X,F4.1	meters	WAVEH	Wave Height
1X,F4.1	meters	SWELLH	Swell Height

TABLE B-3. FORMAT LINE #2

Format	Units	Variable Name(s)	Description
6X			Blank
1X,F5.2	m/sec	WNDSPD,V	Wind Speed
1X,F5.2	m/sec	AVWSD	Average Wind Speed over past 12 hours
1X,I2	10 deg.	IWINDD	Wind Direction (from)
1X,F4.1	km	VISRO	Visual Range Observed
1X,F4.1	km	VISCAL	Visual Range Calculated
1X,I2	Okta (1/8)	ITC	Total Cloud Cover
1X,I2	Okta (1/8)	LCC,ICLT	Lower Cloud Cover (Amount)
1X,I2	Code	ILC	Lower Cloud Type (0 to 9)
1X,I2	Code	IMC	Medium Cloud Type (0 to 9)
1X,I2	Code	IHC	High Cloud Type (0 to 9)
1X,F5.0	meters	CHT	Lower Cloud Height
1X,E10.3	m^(-2/3)	CN2	Index of Refraction Structure Factor Squared
1X,F5.2	mm/hr	RNRT	Rain Rate (derived from IWEAT)

TABLE B-4. FORMAT LINE #3

Format	Units	Variable Name(s)	Description
6X			Blank
1X,F7.4	km-1	EXT055	0.55 micrometer Extinction Coef. at 10 km = -ln(Trans(10))/10
1X,F4.3		XN055	Range correction Coef. for above*
1X,F7.4	km-1	EXT080	0.80 micrometer Extinction Coef. at 10 km = -ln(Trans(10))/10
1X,F4.3		XN080	Range correction Coef. for above*
1X,F7.4	km-1	EXT106	1.06 micrometer Extinction Coef. at 10 km = -ln(Trans(10))/10
1X,F4.3		XN106	Range correction Coef. for above*
1X,F7.4	km-1	EXT34_5	Band Average Extinction Coef. over 3.4 to 5 micrometer band at 10 km = -ln(Trans(10))/10 (weighted by temperature derrivative of black-body function at 293K)
1X,F4.3		XN34_5	Range correction Coef. for above*
1X,F7.4	km-1	EXT8_12	Band Average Extinction Coef. over 8 to 12 micrometer band at 10 km = -ln(Trans(10))/10 (weighted by temperature derrivative of black-body function at 293K)
1X,F4.3		XN8_12	Range correction Coef. for above*

*See discussion of Equations (B-1), (B-2), and (B-3) earlier.

TABLE B-5. FORMAT LINE #4

Format	Units	Variable Name(s)	Description
6X			Blank
F6.2	m	delta	Evaporation Duct Height
1X,F6.1	N units	Ns	Radio Refractivity Ns=(n-1)*1.E6 where n is index of refraction
1X,F7.4	km-1	xmmt17	total extinction at 17 GHz
1X,F7.4	km-1	xmmt35	total extinction at 35 GHz
1X,F7.4	km-1	xmmt95	total extinction at 95 GHz

Notes: Total mm wave extinction includes contribution from dry air, water vapor, rain and fog.

TABLE B-6. FORMAT LINE #5

Format	Units	Variable Name(s)	Description
2X			Blank
1X,F5.3	km-1	EXT34_38	Band Average Extinction Coef. over 3.4 to 3.8 micrometer band*
1X,F4.3		XN34_38	Range correction Coef. for above*
1X,F5.3	km-1	EXT38_42	Band Average Extinction Coef. over 3.8 to 4.2 micrometer band*
1X,F4.3		XN38_42	Range correction Coef. for above*
1X,F5.3	km-1	EXT44_46	Band Average Extinction Coef. over 4.4 to 4.6 micrometer band*
1X,F4.3		XN44_46	Range correction Coef. for above*
1X,F5.3	km-1	EXT46_48	Band Average Extinction Coef. over 4.6 to 4.8 micrometer band*
1X,F4.3		XN46_48	Range correction Coef. for above*
1X,F5.3	km-1	EXT48_5	Band Average Extinction Coef. over 4.8 to 5.0 micrometer band*
1X,F4.3		XN48_5	Range correction Coef. for above*
1X,F5.3	km-1	EXT8_10	Band Average Extinction Coef. over 8.0 to 10.0 micrometer band*
1X,F4.3		XN8_10	Range correction Coef. for above*
1X,F5.3	km-1	EXT10_12	Band Average Extinction Coef. over 10.0 to 12.0 micrometer band*
1X,F4.3		XN10_12	Range correction Coef. for above*

*See discussion of Equations (B-1), (B-2), and (B-3) earlier.

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An important factor in calculating performance ranges for thermal imaging sensors (TIS) is the atmospheric transmission. The infrared energy from a target must first pass through a section of the atmosphere before reaching the TIS aperture. This atmosphere will attenuate the signal. The amount of attenuation depends on the sensor band and weather conditions, and may have a considerable affect on the strength of the received signal. Usually a complex program such as *LOWTRAN 7* is used to calculate the atmospheric transmission for a given range and set of weather conditions, but this can be time-consuming and involves the specification of many variables. In an attempt to simplify this process, weather information previously combined into databases was processed into a form that would allow simple estimates of TIS band atmospheric transmission at any given range at various levels of probability of occurrence. Three of these databases, the *Random 400* (R400), the *Random 384* (R384), and the *Random 10,000* (R10K), represent a *worldwide sample* of a larger collection of weather data, known as the Naval Surface Warfare Center, Dahlgren Division Environmental database. A fourth database, the *Persian Gulf 720* (PG720) describes only one specific location. This report describes these databases and the TIS band transmission modeling that was performed using them.

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